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Research Note

Modelling the Intervention of UAH/USD Exchange Rates as a Result of 2022 Russian Invasion of Ukraine

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Abstract

Russia and Ukraine are in a war, with the former invading the latter. This puts the latter under great stress, many have died in the process and many more have been displaced and many more have fled from Ukraine. This has resulted in intervention in many time series related to Ukraine. For example, the time series of the daily exchange rates of Ukrainian Hryvnia (UAH) and United States Dollars (USD) experienced an intervention on the first day of Russian incursion. By Box and Tiao (1975) approach, a realization of the time series from 1 January 2022 to 15 March 2022 is analyzed. The intervention model arrived at is found adequate. It can be the basis for management and planning.

Keywords: Ukrainian Hryvnia (UAH), United States Dollars (USD), exchange rates, intervention, Russian invasion of Ukraine.

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Introduction

Since 24 February 2022 Russia has invaded Ukraine and unrelentingly has wrought damage to the latter. United States on the other hand is experiencing relative peace and tranquility. This study looks at the behavior of the Ukrainian Hryvnia (UAH) and the United States Dollars (USD) exchange rates within this time frame. It is observed that an intervention developed in the time series after Russia struck on 24 February 2022. In the sequel the intervention model is proposed and shown to be adequate for the series. The approach used is the Box and Tiao (1975) method, which has been successfully applied by many authors.

Ray *et al.* (2014), for instance, studied intervention introduced by using the Bt cotton variety in 2002 to cotton cultivation in India. They noticed that the use of ARIMA intervention model gave better results than the use of conventional ARIMA modeling. In Malaysia in 2001, a road safety intervention was introduced called OPS Sikap. It was observed that ARMA(1,12) was the best intervention model used for the prediction of the number of road accidents. In Nigeria Federal Road Safety Corps was established in 1987 for the same purpose as OPS Sikap in Malaysia. Oreko *et al.* (2017) have confirmed that the establishment of this intervention measure has achieved the purpose for which it was adopted. Giordano *et al.* (2020) studied the incidence of covid-19 in Italy, and arrived at the conclusion that restricted social distancing and tests are capable of arresting covid-19 epidemic in Italy. Mohammed *et al.* (2016) adopted interrupted time series approach to ascertain whether intervention measure used the Ghanaian government in the year 2001 was effective in the reduction of inflation in Ghana. Using yearly series of inflation and the Box-Jenkins (1976) technique, it was found that autoregressive model of order 1 was suitable for the series. Also, the intervention measure was effective in curbing inflation in the economy. Ma *et al.*(2013) used interrupted time series approach to find out if the intervention of raising taxes on cigarettes could lower smoking prevalence among Pennsylanian populace. They observed a significant decrease in the prevalence. Etuk and Eleki (2016) have shown by the application of the algorithm of Box and Tiao that there was an intervention of economic recession in Nigeria to significantly affect the daily Chinese Yuan and Nigerian Naira exchange rates. Helfenstein (1991) discusses the use of ARIMA models in modeling interventions in the field of Epidemiology. This is to mention just a few.

Materials and Methods

Data

The data analyzed in this work are 74 daily UAH/USD exchange rates from 1 January 2022 to 15 March 2022 obtainable from the website (https://exchangerates.org.uk/UAH-USD-spot-exchange-rates-history-2022.html). They are to be interpreted as the amount of USD going for one UAH (∅ 1 UAH).

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Intervention Modelling

Suppose $X_1, X_2, \ldots, X_n$ is a realization of a time series $\{X_t\}$ having an intervention at time $t = T < n$. According to Box and Tiao (1975), the pre-intervention series is modeled as an ARIMA(p,d,q). That is,

$$\nabla^d X_t = \alpha_1 \nabla^d X_{t-1} + \alpha_2 \nabla^d X_{t-2} + \cdots + \alpha_p \nabla^d X_{t-p} + \varepsilon_t + \beta_1 \varepsilon_{t-1} + \beta_2 \varepsilon_{t-2} + \cdots + \beta_q \varepsilon_{t-q} \quad \ldots.. \quad (1)$$

where $t<T$, $\nabla = 1-L$ where L is a backshift operator defined by $LX_t = X_{t-1}$, $\{\varepsilon_t\}$ a white noise process and $\{\alpha_i\}$ and $\{\beta_j\}$ are constants chosen so that model (1) is stationary and invertible. (1) may be written as

$$\nabla^d \left(1 - \alpha_1 L - \alpha_2 L^2 - \cdots - \alpha_p L^p\right) X_t = \left(1 + \beta_1 L + \beta_2 L^2 + \cdots + \beta_q L^q\right) \varepsilon_t \quad (2)$$

Or

$$\nabla^d A(L) X_t = B(L)\varepsilon_t \quad (3)$$

Where $A(L)=1-\alpha_1 L-\alpha_2 L^2-\ldots-\alpha_p L^p$ is the autoregressive operator and $B(L) = 1+\beta_1 L+\beta_2 L^2+\ldots+\beta_q L^q$ is the moving average operator.

The noise part of the intervention model is

$$X_t = B(L)\varepsilon_t / A(l)\nabla^d \quad (4)$$

Let f(t) be the post-intervention forecast on the basis of (1). Suppose $z=X_t-f(t)$, $t \geq T$. Then the transfer function of the intervention model is given by

$$Z=c_1*(1-c_2\hat{}(t-T+1))/(1-c_2),\ t \geq T \quad (5)$$

Combining (4) and (5) the intervention model is

$$Y_t = B(l)\varepsilon_t / A(L)\nabla^d + I_t c_1*(1-c_2\hat{}(t-T+1))/(1-c_2) \quad (6)$$

where $I_t = 0$, $t< T$ and $I_t = 1$, $t \geq T$.

Computer Software:

Eviews 10 was used for all computational need of this work.

Results

The time plot of daily exchange rates of UAH and USD is in Figure 1. There is a generally negative trend. The intervention happens at t=T=55, that is, at February 24, 2022, the day that Russia struck Ukraine. The pre-intervention series has its time plot in Figure 2. Shown is a generally downward trend. Table 1 shows unit root test of the pre-intervention series. With p-value equal to 0.8872 > 0.05, the pre-intervention series is found non-stationary. There was therefore need for differencing. Figure 3 shows a time

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plot of the difference of the series. There is no more trend. The unit root test of Table 2 shows that the difference of the pre-intervention series is stationary having a p-value of $0.0000 < 0.05$. Figure 4 is the correlogram of the difference series. It suggests an autocorrelation structure of a white noise process, none of the spikes being statistically significant. This means that the post-intervention forecasts are equal to the last pre-intervention rate of 0.0341. With $f=0.0341$, $t > 54$, $z=X_t - f$, $t > 54$.

The transfer function determined in Table 3 is such that $c_1 = -0.000672$ and $c_2 = -0.125936$. The intervention model forecasts compared to post-intervention data in figure 5 are close. the intervention model is therefore

$$Y_t = \varepsilon_t/\nabla - 0.000672*(1-(-0.125936)\wedge(t-54))/1.125936, \ t > 54 \quad (7)$$

The chi-square statistic value of 0.0484 is less than the critical value of $30.144 = \chi^2_{0.05}$ at degree-of-freedom 19. The non-significant Pearson's goodness-of-fit test of Table 4 is a testimony to the adequacy of the intervention model.

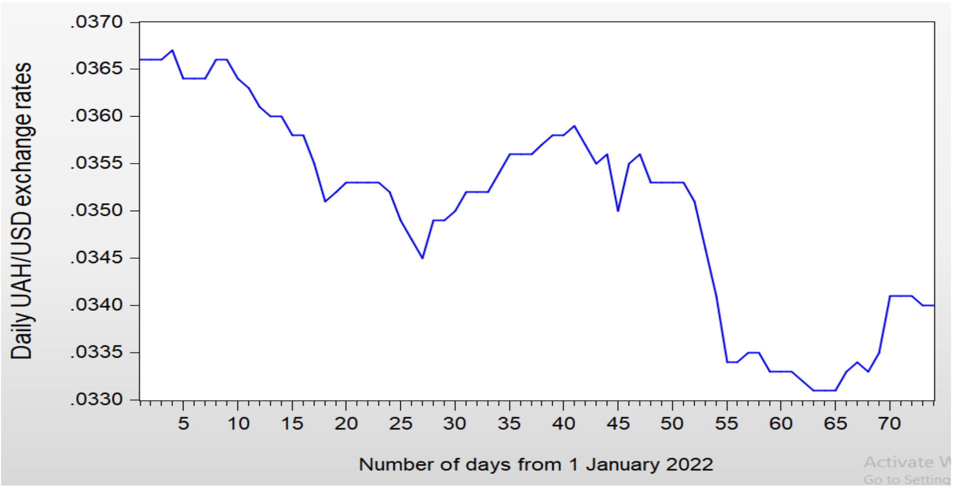

Figure 1: Time plot of the UAH/USD exchange rates

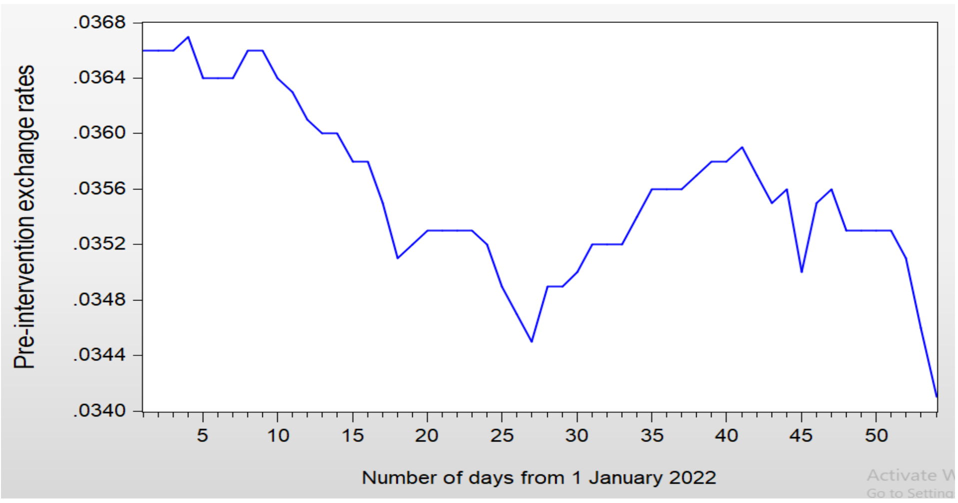

Figure 2: Time plot of the pre-intervention series

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Table 1: Unit root test on the pre-intervention series

Null Hypothesis: UAHD has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.258669	0.8872
Test critical values:	1% level	-4.140858	
	5% level	-3.496960	
	10% level	-3.177579	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(UAHD)
Method: Least Squares
Date: 03/16/22 Time: 09:13
Sample (adjusted): 2 54
Included observations: 53 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
UAHD(-1)	-0.081936	0.065098	-1.258669	0.2140
C	0.002950	0.002361	1.249739	0.2172
@TREND("1")	-2.95E-06	2.44E-06	-1.211899	0.2312

R-squared	0.036001	Mean dependent var	-4.72E-05
Adjusted R-squared	-0.002559	S.D. dependent var	0.000209
S.E. of regression	0.000209	Akaike info criterion	-14.05069
Sum squared resid	2.19E-06	Schwarz criterion	-13.93916
Log likelihood	375.3433	Hannan-Quinn criter.	-14.00780
F-statistic	0.933636	Durbin-Watson stat	1.703518
Prob(F-statistic)	0.399866		

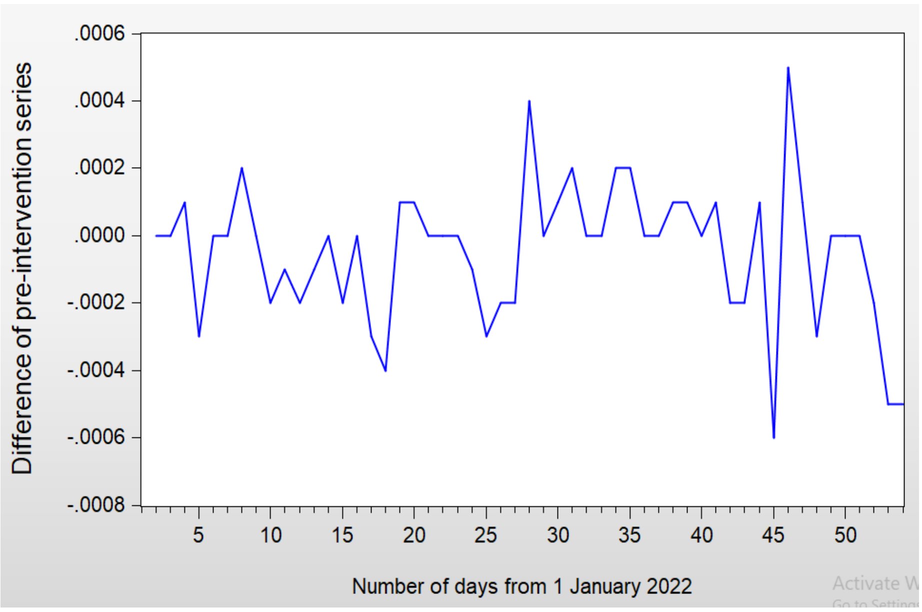

Figure 3: Time plot of difference of pre-intervention series

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Table 2: Unit root test for difference of pre-intervention series

Null Hypothesis: DUAHD has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=10)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.207361	0.0000
Test critical values:	1% level	-4.144584	
	5% level	-3.498692	
	10% level	-3.178578	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(DUAHD)
Method: Least Squares
Date: 03/16/22 Time: 09:19
Sample (adjusted): 3 54
Included observations: 52 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DUAHD(-1)	-0.925613	0.149115	-6.207361	0.0000
C	-1.91E-05	6.23E-05	-0.306940	0.7602
@TREND("1")	-9.49E-07	1.98E-06	-0.479734	0.6336

R-squared	0.441573	Mean dependent var	-9.62E-06
Adjusted R-squared	0.418780	S.D. dependent var	0.000281
S.E. of regression	0.000214	Akaike info criterion	-14.00355
Sum squared resid	2.25E-06	Schwarz criterion	-13.89098
Log likelihood	367.0923	Hannan-Quinn criter.	-13.96039
F-statistic	19.37320	Durbin-Watson stat	1.933483
Prob(F-statistic)	0.000001		

Date: 03/16/22 Time: 09:21
Sample: 1 54
Included observations: 53

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.068	0.068	0.2556	0.613
		2	0.007	0.002	0.2581	0.879
		3	0.082	0.082	0.6542	0.884
		4	-0.110	-0.123	1.3790	0.848
		5	0.104	0.124	2.0397	0.844
		6	0.037	0.011	2.1260	0.908
		7	-0.032	-0.015	2.1910	0.949
		8	0.062	0.034	2.4380	0.965
		9	0.077	0.095	2.8263	0.971
		10	-0.082	-0.103	3.2770	0.974
		11	0.016	0.015	3.2956	0.986
		12	0.092	0.097	3.8981	0.985
		13	-0.072	-0.069	4.2761	0.988
		14	-0.181	-0.232	6.7237	0.945
		15	-0.037	0.015	6.8269	0.962
		16	-0.020	0.029	6.8595	0.976
		17	-0.213	-0.278	10.537	0.880
		18	-0.009	-0.002	10.545	0.913
		19	-0.114	-0.023	11.651	0.900
		20	-0.070	-0.070	12.088	0.913
		21	-0.102	-0.227	13.033	0.907
		22	-0.103	0.081	14.028	0.900
		23	-0.168	-0.189	16.763	0.821
		24	-0.065	-0.149	17.193	0.840

Figure 4: Correlogram of difference of pre-intervention series
f=0.0341, t > 54

Table 3: Determination of the transfer function of the intervention model

Dependent Variable: Z
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 04/19/22 Time: 14:26
Sample: 55 74
Included observations: 20
Convergence achieved after 13 iterations
Coefficient covariance computed using outer product of gradients
Z=C(1)*(1-C(2)^(T-54))/(1-C(2))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.000672	0.000352	-1.907024	0.0726
C(2)	-0.125936	0.601174	-0.209483	0.8364

R-squared	0.003205	Mean dependent var	-0.000600
Adjusted R-squared	-0.052172	S.D. dependent var	0.000354
S.E. of regression	0.000363	Akaike info criterion	-12.90948
Sum squared resid	2.37E-06	Schwarz criterion	-12.80990
Log likelihood	131.0948	Hannan-Quinn criter.	-12.89004
Durbin-Watson stat	0.231557		

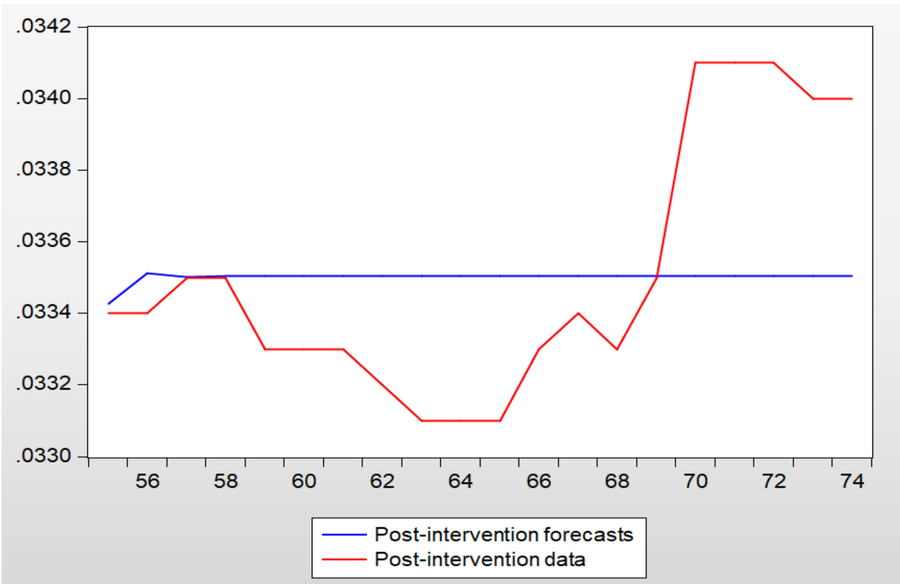

Figure 5: Superimposition of the post-intervention forecasts on the post-intervention data

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Table 4: Pearson's chi-square Goodness-of-fit test

Post-intervention forecasts (1)	Post-intervention data (2)	((1)-(2))^2/(1)
0.033428	0.0334	0.0000000235
0.033513	0.0334	0.000000379
0.033502	0.0335	0.000000000116
0.033503	0.0335	0.000000000328
0.033503	0.0333	0.00000123
0.033503	0.0333	0.00000123
0.033503	0.0333	0.00000123
0.033503	0.0332	0.00000274
0.033503	0.0331	0.00000485
0.033503	0.0331	0.00000485
0.033503	0.0331	0.00000485
0.033503	0.0333	0.00000123
0.033503	0.0334	0.000000318
0.033503	0.0333	0.00000123
0.033503	0.0335	0.00000299
0.033503	0.0341	0.0000106
0.033503	0.0341	0.0000106
0.033503	0.0341	0.0000106
0.033503	0.034	0.00000737
0.033503	0.034	0.00000737
Total		0.0484232

Conclusion

It is not surprising that invasion of Ukraine by Russia has produced many interventions in Ukraine. The UAH/USD exchange rates series is just aan example of many time series involved. Intervention model (7) adequately suits the data . It will be found important to managers and planners.

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